F. No. 32/645/2017-SPV Division
Government of India
Ministry of New and Renewable Energy
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Block no. 14, CGO Complex,
Lodi Road, New Delhi -110003
Dated: 10th April 2019

Office Memorandum

Subject: Request for comments of stakeholders on draft specifications and testing procedure for Universal Solar Pump Controller (USPC).

Government has recently approved scheme for farmers for installation of solar pumps and grid connected solar power plants. Administrative Approval for the scheme was issued by Ministry of New & Renewable Energy (MNRE) on 08.03.2019.

2. In order to increase the utility of the solar PV system installed for solar water pumps, it is proposed to consider use of Universal Solar Pump Controller (USPC). Draft specifications and testing procedure for USPC have been formulated and enclosed herewith for consultations. Stakeholders are requested to send their comments/suggestions/views on these documents latest by 19.04.2019 at shobhit.srivastava@nic.in.

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Scientist-E

To
All concerned stakeholders

Universal Solar Pump Controller (USPC)

USPC Specifications for Stand alone and On Grid applications:

1. Preamble:

The Controller for Solar Water pumping System is the heart and brain of the system made of SPV Panels, Motor and Pump besides Structure. The Solar water pumping system deployed at huge cost to the farmer and the exchequer or the Government is currently utilised only for half of the days in a year (150 days per year) on average as per available credible statistics.

Besides the SPV Panels last for 25 years and therefore other constituents of the solar pumping system must have the design and quality to last that many years. Keeping both these aspects in mind the Controller design should be such that besides water pump it should be able to run any agrarian equipment that will help farmer to raise productivity and quality of the produce and save diesel or other form of fossil based energy. The Controller design should also incorporate features that will take in to account degradation in the panels and other factors like partial shading etc.

Considering past observations, that maximum solar water pumping installation are running for 140 to 160 days of a year and for remaining days they are sitting idle. This is the underutilization of infrastructure (PV, PV structure, controllers, etc.). In order to increase the utilization of solar photovoltaic system, the controller supplied for installation of solar pumping system should perform several other tasks for agricultural and other needs of a farmer to increase the productivity of agriculture sector and income of farmer. With the use of USPC the solar system could be used more than 300 days in a year:

The Controller should therefore be such that when irrigation is not required, the farmer can clean his crop with Winnower/Thresher, cut chaff for milch animals, operate cold storage to preserve his crop or deep freezer to store agrarian/dairy produce etc. This will save the farmer diesel cost, get higher market value for his produce and raise income many fold.

The Controller for Solar Pump System should besides Pump be able to run any agrarian load with in the given rating can be christened as Universal Solar Pump Controller or in short USPC.

The philosophy is that when solar energy is converted to electrical energy by SPV panels, the Controller should be able to power any load that can otherwise be powered by the Grid. Such Controller shall be called USPC.

2. Proposed Technical Specification for Stand Alone and On Grid Application

1. The scope of work is:

   (A) To install USPC with SPV modules, Structure and Pump set, in short Solar System for irrigation purpose with capabilities to perform multiple auxiliary functions like energizing agrarian equipment: Apple grading and polishing system, Wheat (grain) floar grinding machine / Aata chakki, Cutter/chaff, Deep-fridger / cold storage, Blower fan for cleaning of grains, Any other standard voltage (400/415V) three phase motor.

These equipment are ranging from capacity 3 HP to 10 HP. USPC should have robust system protection features, remote fault monitoring etc.

(b) To install USPC based solar system as above plus capabilities to export power to the grid when pumping is not in operation.

If in case farmer wishes to apportion the power between Motor/Pump set and Grid: Algorithm i.e. Software should provide that facility. This kind of situation may arise when Farmer's requirement for irrigation (discharge) can be met by less power than installed power. This will save ground water depletion, crop loss due to overwatering will be avoided and thus raise productivity and result in to higher income for farmer, besides un used SPV power fed to the grid will further raise farmer's income.

2. Following Table suggest desired Photovoltaic panel ratings for USPC/Motor-Pump set of capacities ranging from 3 to 10 HP.

Sr No.	Existing Motor Pump set capacity	PV panel rating (STC)
1	3 HP	2800W to 3100W
2	5 HP	4800W to 5000W
3	7.5 HP	6750W to 7200W
4	10 HP	9000W to 9500W

Note: For other technical specification of 12 HP and 15 HP system, 10 HP equivalent specification can be referred.

3. Following table gives specifications of electrical supply from USPC.

Sr No.	Description	Desired requirement
1	Motor Supply Phases	Three phase R-Y-B
2	Rated motor frequency	48-50Hz
3	Frequency operation	0 to 52Hz
4	Rated motor voltage	380V to 415V
5	Desired motor operation	Constant V by F or constant motor flux control

4. Proposed electrical properties of USPC based solar pumping system should be as follows:

Sr No.	Description	Desired requirement
1	Characteristic of voltages	Pure sinusoidal or Filtered AC output voltage at motor terminal. No PWM pulses allowed for

		submersible motor-pumps with head 30mtr or above, as it generates pronounced voltage spikes.
2	THD of motor terminal voltages	Below 3%
3	THD of motor current (in case of balance/linear motor)	Below 5%
4	Balance supply	Three phases should be balanced and no negative sequence components to be allowed
5	Voltage spikes	Recurring or non-recurring voltage spikes more than 700V is not allowed between any two terminals

Controller should be designed to run four out of following equipment:

(i) Apple grading and polishing system

(ii) Wheat (grain) flour grinding machine / Aata chakki

(iii) Cutter/chaff,

(iv) Deep-fridger / cold storage

(v) Blower fan for cleaning of grains. (Winnower/Thresher)

(vi) Any other standard voltage (400/415V) three phase motor.

But to begin with the new trend of USPC, following are the initial targeted applications which are very useful for all categories of farmers based on their type of crop.

(i) Traditional solar water pumping systems as per MNRE 2017-18 norms ranging from capacity 3 HP to 10 HP, different heads of submersible and monoblock/shallow well submersible pumps.

(ii) Cutter 3 HP capacity, Size: 1 meter diameter, Two or three blade cutter, Production rate: 60 to 75kg per hour for 3 HP cutter.

(iii) Atta chakki 3 HP capacity: size 14inch, open hopper, stone type, production rate: 14 to 18 Kg/hour, hopper size:15 to 20Kg

(iv) Deep fridger: 500Ltr capacity, temperature range 0 to -22 degC, Refrigerant gas R22, cooling type room temperature to -22 degC in 6 fours, Horizontal frozen type with three phase parallel connected exhaust fan of 100W capacity. Compressor motor and exhaust fan should work on a same supply lines from the PV fed USPC controller.

5. To ensure energy efficiency of solar PV system and to maintain reliability of PV installation against aging effect, module mismatch with time, partial shading, etc. , the desired USAC properties and configuration should be as follows:

(a) MPPT efficiency of USPC should be equal or more than 98% during operation of 10 to 100% of rated STC PV power, so as to maintain MPPT irrespective of variation in solar energy or irradiance.

(b) USPC efficiency should be as follows for the operation above 80% rated STC power:

Sr No.	Existing Motor Pump set capacity	Controller power efficiency should be more than or equal to
1	3 HP	93.00%
2	5 HP	93.00%
3	7.5 HP	94.00%
4	10 HP	94.50%
5	15 HP	94.50%

(c) Considering effect due to ageing, environmental damages to PV panels with time, USPC should have MPPT channels as an integral part of system (or externally connected part) with wide range of input PV voltage for MPPT tracking of the PV panels. Input voltage range variation without reducing MPPT efficiency should be as given in following Table: This confirms to International and European Standards, most motably IEC 61683 and EN 50530. NISE has been certifying OnGrid and also Pump Controller as per these standards for last several years.

Sr No.	Motor Pump set capacity	Input voltage range (without reducing MPPT) should be more than:
1	3 HP	(Vnominal+50) to (Vnominal-50)
2	5 HP	(Vnominal+70) to (Vnominal-70)
3	7.5 HP	(Vnominal+70) to (Vnominal-70)
4	10 HP	(Vnominal+100) to (Vnominal-100)
5	15 HP	(Vnominal+100) to (Vnominal-100)

3. **Stand alone USPC powering agrarian and other machinery**

Data collected on the basis of Remote Monitoring of installed pumps in MNRE schemes, on an average solar water pumping installation is used for irrigation purpose, maximum 150 to 160 days a year. This is criminal waste of installed power capacity and under-utilization of infrastructure (PV, PV structure, controllers, etc.). It drastically reduces the value of complete system. It is a loss to exchequer and in fact national loss.

To increase the utilization of solar photovoltaic system, the controller, i.e. USPC supplied for installation of solar pumping system where three phase grid is not available should perform following tasks with and without battery support for agricultural operations and similar kind of applications. In most agrarian operations, predominantly diesel is used to energize the equipments like Chaff/Cutter, Blower and Thresher etc. Available SPV power could be used to perform these tasks only if Controller (USPC)

is capable of providing starting torque to these equipments. Replacing use of diesel by SPV Power/Energy is the stated aim of CFA to all Solar/Renewable schemes, Off-Grid or On-Grid.

(a) USPC should be laced with facility to interface batteries as per user's wish and based on applications and capacity requirement.

(b) Farmers must be equipped with USPC, PV power and motor control to run his other applications such as chaff cutter, threshers/blowers, grinders, and so on, so that he can take a decision to invest into this system. Controller, i.e. USPC must have architecture and software capabilities to operate such agrarian equipments.

(c) The USPC supplied in the project should be able to run mini-cold storages at farms so that agriculture produce can be stored as per requirement of farmers and as per installation capacity. USPC should be able to run compressor load and other auxiliary elements associated with cold storage such as temperature controller, blowers, solenoid switch, etc. The cold storage, battery and its installation may be in the scope of user/farmer.

(d) The solar controller, i.e. USPC supplied in the project should be able to run Bilk milk chillers as per capacity of the installation. USPC should be able to run compressor load and other auxiliary elements associated with Bulk milk chiller such as stirrer, temperature controller, blowers, solenoid switch, etc. The bulk milk chiller, battery and its installation may be in the scope of user/farmer. This will give enormous boost to dairy farming as integral part of agriculture, raising farm household's income manifold.

(e) Solar system with USPC supplied in the project should be able to run blower fan for cleaning of grains. Many studies have suggested that by virtue of cleaning alone farmer realizes 30 % more price for the crop! Farrmer will not have to use tractor power to run the blower fan, thus freeing tractor for cultivation, is the added and most important advantage.

There should be Mode selection located on control panel of the solar controller, i.e. USPC along with display and user should be able to switch select either one of the above applications. No external switch box should be allowed and application selection switch must be integral part of the USPC/Controller. Software selection of application by way of mobile application must also be provided to the user/farmer.

The block diagram of solar agriculture controller is shown in Fig. 1.

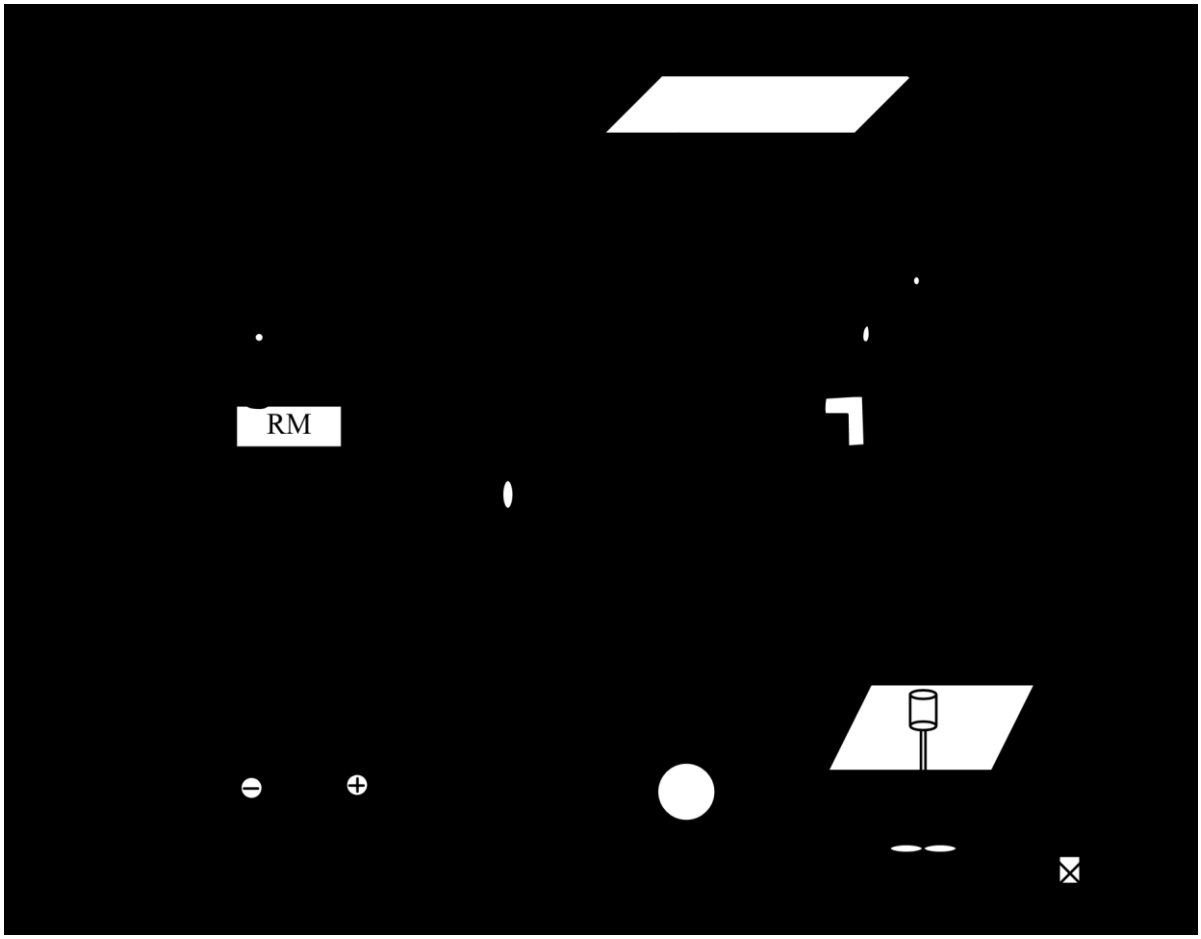


Fig. 1. Solar agriculture controller for the places where three phase grid is not available.

Solar agriculture controller (USPC) should have MPPT ports for Solar PV and provision for battery using bidirectional converter. For capacity of agriculture controller more than 7.5 HP, there must be multiple channel MPPT to enhance efficiency, to reduce degradation problems and to reduce partial shading problems.

4. **Grid connected USPC specifications**:

The suggested project involving the replacement of existing pump connection with three phase grid supply system may possess following features:

(a) Solar pump controller, USPC should be operated as per user's wish for either water pumping or grid export. This facility should be either by way of switch selection built in the controller (and no external switch box for selection) or software selection, possibly by mobile app.

(b) USPC should be equipped with mode change-over switch for either pumping or for grid export of PV power, thus when pumping is not required user/farmer should sell power to the grid.

(c) Solar Controller should monitor the grid supply and provide anti-islanding protections in case of grid failure, when grid export is selected.

(d) USPC Controller should not inject DC current and harmonics into the grid and compliance with IEEE1457 and its versions related with grid interface and operation must be strictly adhered to. Otherwise load down the line will be severely affected.

The block diagram of USPC/Controller showing Grid connection or Motor-Pump set is shown in Fig. 2.

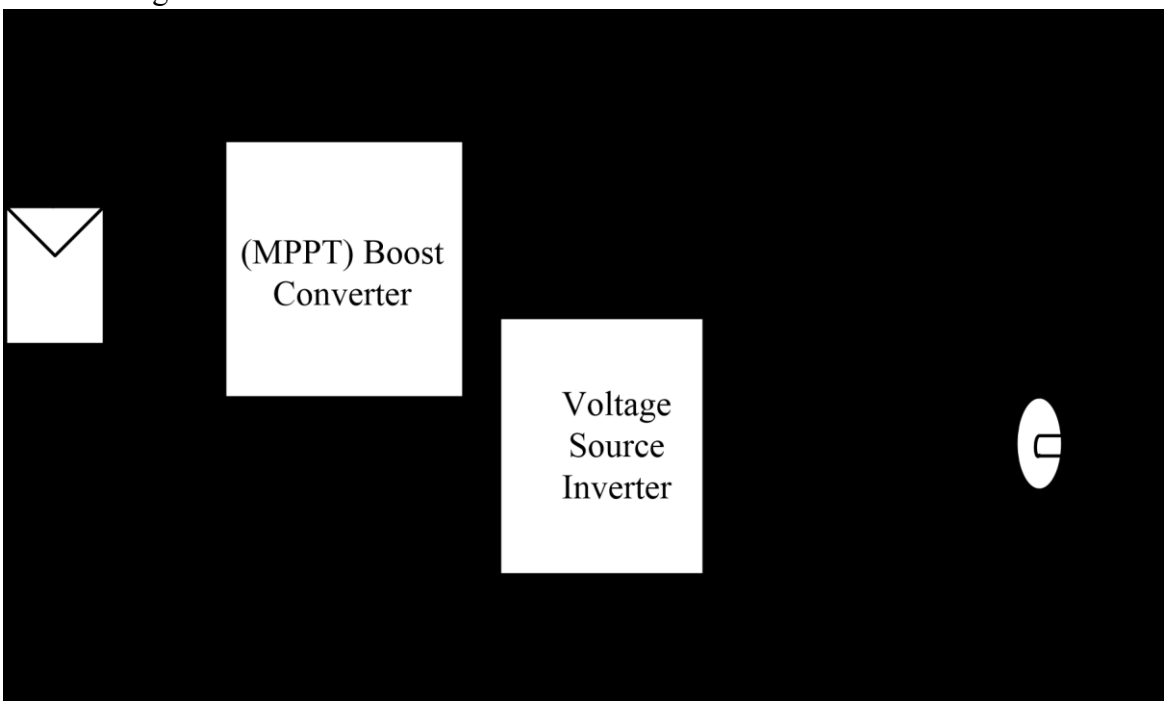


Fig. 2 Block diagram of controller used for running agriculture pump and feed power to the grid.

Common MPPT BOOST CONVERTER is must. It ensures Input energy efficiency of the entire system. Power flowing to Motor/Pump set or Grid or any other load will be after achieving 98 % plus efficiency. It is must by International, European and even standards set by NISE for grid tied inverters. With common Controller function, USPC for Grid and Pump set: obviously the standards set for On-Grid must prevail. And On-Grid Inverter standard set by NISE, IEC 61683 or EN 50530 suggests MPPT of 98% plus for entire profile or Input Power ranging from 10 to 100 % and over 3 voltage levels, that is Vnominal and Vmax and Vmin of 70 to 100 Volts, depending upon rating of the Motor/Pump set.

USPC based Solar system must be equipped with Remote monitoring and remote fault identification:

(a) Remote monitoring features should be integral or external part of solar pump controller and should provide time wise remote monitoring of PV voltage, PV Power, motor voltage, motor current and motor frequency, etc.

(b) Cumulative energy generation from PV panels for a month, year and 5years should be provided.

(c) Remote monitor should show current status of system like On, Off and fault.
(d) Software associated with remote monitoring should also provide location of system and mobile friendly map to reach the system for maintenance.
(e) Controller should have support of SD card / memory card to support remote monitoring in case of network failure.

USPC must have IP54 protection or must be housed in a cabinet having at least IP54 protection.

Earthing and Lightning Protection:

Earthing: The array structure of the PV yard shall be grounded properly using adequate number of earthing kits. All metal casing or shielding of the pumping system shall be thoroughly grounded to ensure safety of the solar pumping systems.

Lightning Arrester: The SPV Power Plant shall be provided with lightning & over voltage protection for installation 10 HP and above. The main aim in this protection shall be to reduce the over voltage to a tolerable value before it reaches the PV or other sub system components. The source of over voltage can be lightning, atmosphere disturbances, etc.

5. USPC add on specifications-Optional:

As single phase supply is available at many places, universal solar pump controller should have a provision to couple with single phase AddOns to run the motor pump set even when solar radiation is not available. Auto-changeover should be possible to switch from PV to grid and from grid to PV depending upon the status of solar radiation. Property of Single phase AddOns is as follows:

(a) Input voltage: Standard 230V, 50Hz supply

(b) Input voltage range: 110 to 250V AC rms

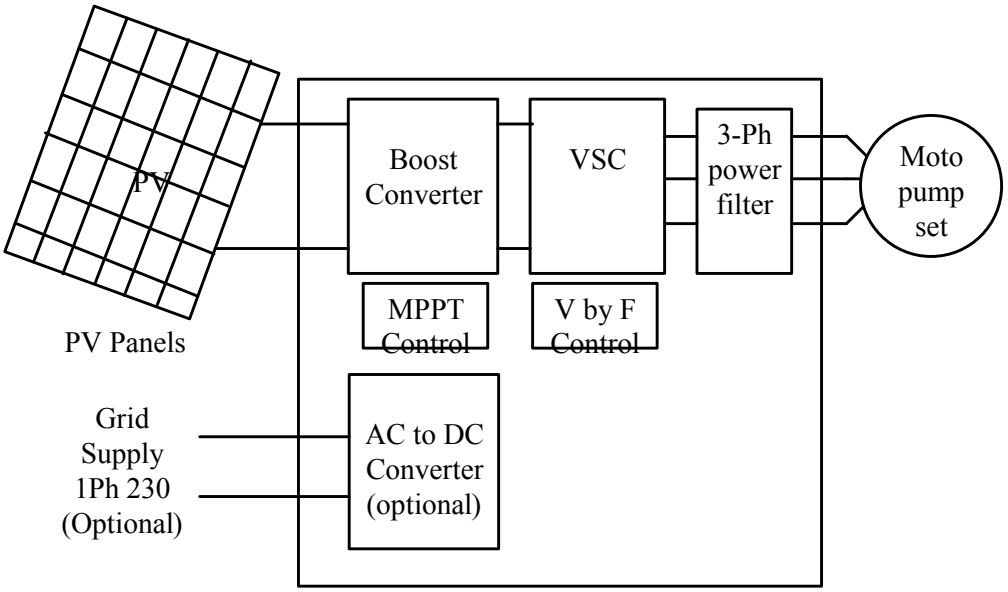
(c) Current extraction power quality: THD < 3% from 10 to 100% of rated current

(d) No load losses below 2%

(e) Changeover automatic

(d) Power factor above 0.97 (unity power factor operation)

One of the possible ways of providing single phase support to run application during night/ no light condition is shown as follows. Below is block diagram of unity power factor based 1Phase AddOns to multifunction solar pump controller which is optional and will be provided on demand of customer:


PV
PV Panels
Boost Converter
VSC
3-Ph power filter
Moto pump set
MPPT Control
V by F Control
Grid Supply 1Ph 230 (Optional)
AC to DC Converter (optional)

Testing Procedure for Universal Solar Pump Controller (USPC)

Universal Solar Pump controller should be capable of running minimum four applications by selecting appropriate options through software; one of them must be either AC or DC Pump. Following applications are indicative and besides water pump other three can be any inductive load in the agriculture operation.

(i) Water Pumping
(ii) Chaff Cutter
(iii) Deep fridge/ Cold Storage
(iv) Atta Chakki

2. There should be no manual change over and application selection by the user should be through software and keyboard. Universal Solar Agriculture controller should have multiple outputs, precisely four in number. The output can be permanently connected to any of the applications and selection of application must be through keyboard.

3. Application Specific output (Application specific software): USPC should have inbuilt individual application specific software to select and run any one of the above applications.

4. Application description on screen and selection of applications: LCD screen provided on controller must display available application, which can be selected by keypad on the controller.

5. Application wise test details:

a) Solar Water Pumping

S.No.	Tests to be Performed	Remark
1.	Input voltage range Minimum – Voc at STC Nominal – Voc at STC Maximum – Voc at STC	MPPT tracking should be measured 50 volts over and above nominal Voc in case of 3 HP, 70 volt incase of 5 and 7.5 HP and 100 volt in case of 10 HP system. This is because voltage varies over the year due to variation in temperature and irradiance.
2.	Ripple and distortion at output on full load	Below 5%
3.	Insulation resistance	Insulation resistance should be tested as per the rated voltage of the system 600 V or 1000 V
4.	Output voltage (Sine Wave)	Three phase output with up to 440 V rms pure Sine Wave
5.	Low radiation mode protection	USPC should shutdown at the low radiation if power is not sufficient to drive the particular application and indicate low radiation and Voc value on LCD and operation range for VOC
6.	Dry run protection	USPC should Shut down and Dry run protection active should be displayed on LCD

7.	Reverse polarity protection	Should have reverse polarity protection so that PV Panel connection do not damage the controller			
8.	Short circuit protection	Pump controller should shut down the output supply within 1 sec			
		and activate short circuit protection and message displayed on LCD			
9.	Open circuit protection	Pump controller should shut down the output supply within 1 sec and activate open circuit protection and message displayed on LCD			
10.	Average MPPT tracking efficiency in Dynamic condition	Should be grater than 98% with hot and cold profiles.			
11.	Output voltage THD at rated PV	Should be less than 5 %			
12.	Instantaneous output voltage and voltage spikes	Output voltage should be Sinusoidal (compulsory output filter) & no voltage spikes should be observed at 50 meter wire length at motor terminals.			
13.	Crest Factor in output voltage at rated PPV	1.4			
14.	Efficiency Tests of the Controller at Voltage (420 Voc) To be Measured	Conversion Efficiency (%)	MPPT Efficiency (%)	Overall System Efficiency (%)	Uncertainty Conversion Efficiency (%)
	At 10% of input power				
	At 25% of input power				
	At 50% of input power				
	At 75% of input power				
	At 100% of input power				

b). Solar Based Chaff Cutter

S.No.	Test to be Performed	Remark
1.	Input PV voltage range Minimum – Voc at STC Nominal – Voc at STC Maximum – Voc at STC	MPPT tracking should be measured 50 volts over and above nominal Voc in case of 3 HP, 70 volt incase of 5 and 7.5 HP and 100 volt in case of 10 HP system. This is because voltage varies over the year due to variation in temperature and irradiance.
2.	Output voltage waveform	Three phase output with up to 440 V rms pure Sine Wave
3.	Input PV power range Pnominal	As per MNRE Solar Pump model
4.	Continuous operation started @ radiation and output Power form array	Chaff cutter Operation in loading condition starts at 50 Hz at Irradiance …….W/m2 & DC output …….Watts. (Objective to provide constant 50 Hz operation approx. 9 AM daily.

5.	Cutter rotation speed for 4 pole type cutter	Chaff cutter Motor RPM should not vary beyond 30 RPM in case of twin blade chaff cutter. Proper torque and frequency control should be provided as there is continuous load and no load condition in the chaff cutting operation. Min…… -Max……. RPM at motor pully at 50 Hz operation condition/ after sufficient power to operate chaff cutter/ full load condition.
6.	DC Power in loading condition	It depends on loading condition. So Range of power should be provided
7.	DC Power in non-loaded condition	It depends on chaff cutter mechanical settings. So Range of power should be provided.
8.	Cutter operation at different output from array (Array wattage as MNRE model: Example 4800 Wp array) At 50% Power At 75% Power At 100% Power	Above ……. Watt DC output Cutter should not stop functioning at any load condition. Observation should be recorded. Else low radiation protection should shut down the system and display on LCD.
9.	Motor Rating	3 phase 50 Hz, 4 pole 2 HP, 1400 RPM
10.	Total circuit protection observation	Soft Startup, low radiation protection, overload protection, Open circuit protection Reverse polarity protection
11.	Cutter acceleration	Smooth operation should be provided by Soft start.

C. Solar Based Cold Storage/ Deep Freezer

S. No.	Test Performed	Remarks
1.	Input PV voltage range Minimum – Voc at STC Nominal – Voc at STC Maximum – Voc at STC	MPPT tracking should be measured 50 volts over and above nominal Voc in case of 3 HP, 70 volt incase of 5 and 7.5 HP and 100 volt in case of 10 HP system. This is because voltage varies over the year due to variation in temperature and irradiance.
2.	Input PV power range Pnominal	As per MNRE Solar Pump model
3.	Continuous operation started @ radiation and output Power form array	**Deep Freezer** Operation in loading condition starts at 50 Hz at Irradiance …….W/m2 & DC output …….Watts. (Objective to provide constant 50 Hz operation after approx. 8 AM daily to operate the bulk milk chiller etc. so that energy for cooling can be stored and used to chill milk or other load at faster rate)

4.	Compressor rating	Compressor rating should be 75 % less to solar pump rating as per MNRE guide line Objective: at least 4-5 hour operation at peak load so that there is sufficient energy for cooling the load
5.	Motor rating	As per compressor should be verified and mentioned.
6.	Deep fridge operation at different output array (Array wattage as MNRE model: Example 4800 Wp) At 50% Power At 75% Power At 100% Power	Above ……. Watt DC output deep fridge should not stop functioning at any load condition Observation should be recorded. Else low radiation protection should shut down the system and display on LCD
7.	Peak load of the compressor	Electrical observation Continuous operation found at …….DC Wattage for entire day's profile
8.	Start timing	Should start at 30 Hz frequency (or suggested by compressor manufacturer) within 7 sec of soft start (or suggested by compressor manufacturer)
9.	Delay in start of compressor after every time it is turned off	As per compressor manufacturer or 3 Min
10.	Temperature control	Auto on and off provision should be provided for desired/ target temperature
11.	Operation Range of frequency	For small deep freezer's at 50 Hz And For big compressor 30 to 80 Hz or as per compressor manufacturer rating.
12.	Total circuit protection observation	Soft Startup, low radiation protection, overload protection, Open circuit protection Reverse polarity protection

d. Solar Based Atta Chakki

S.No.	Test Performed	Remarks
1.	Input PV voltage range Minimum – Voc at STC Nominal – Voc at STC Maximum – Voc at STC	MPPT tracking should be measured 50 volts over and above nominal Voc in case of 3 HP, 70 volt incase of 5 and 7.5 HP and 100 volt in case of 10 HP system. This is because voltage varies over the year due to variation in temperature and irradiance.
2.	Input PV power range Pnominal	As per MNRE Solar Pump model

3.	Continuous operation started @ radiation and output Power form array	Atta chakki Operation in loading condition should start at 50 Hz at Irradiance …….W/m2 & DC output …….Watts. (Objective to provide constant 50 Hz operation approx. 9 AM daily.)
4.	Rotation speed	Should be constant at static radiation condition with constant non varying loading condition To be measured at Motor: …… RPM Mill pully: ……. RPM
5.	Atta Chakki type	14 inches, open hopper store type, Production rate 14 to 18 kg/ hour wheat flour, hopper size 15 to 20 kg
6.	Atta chakki motor	3 HP, 400 V, 50 Hz, 1440 rpm
7.	Atta Chakki operation at different output (Array wattage as MNRE model: Example 4800 Wp) Wp array At 50% Power At 75% Power At 100% Power	To be measured (Atta Chakki will not stop functioning) Observation should be recorded Above ……..W/m2 radiation or ……..Watt output from array, Atta Chakki operates at full load satisfactorily. Else below …….. W/m2 or …….Watt output from array, low radiation protection shut downs the system and display on LCD
8.	Production rate	
	with wheat or any desired grain	---------- kg/ hour
9.	Total circuit protection observation	Soft Startup, low radiation protection, overload protection, Open circuit protection Reverse polarity protection